DOCUMENT RESUME

ED 261 674 IR 011 826

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TITLE Thinking and the Design Process. DIUL-RR-8414.
INSTITUTION Laval Univ., Quebec (Quebec).
REPORT NO DIUL-RR-8414
PUB DATE May 84
NOTE 30p.; Paper presented at the International Conference on Thinking (Cambridge, MA, August 19-23, 1984).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Artificial Intelligence; *Cognitive Structures; *Computer Science; *Concept Formation; Creative Thinking; *Designers; Diagrams; Information Systems; Models; *Systems Analysis; Systems Approach; *Systems Development

ABSTRACT

Designed to focus attention on the design process in such computer science activities as information systems design, database design, and expert systems design, this paper examines three main phases of the design process: understanding the context of the problem, identifying the problem, and finding a solution. The processes that these phases involve, such as learning, reasoning, modeling, and creating, are identified and presented through the use of a model of mental representation which is built on the base of associated concepts. This model then provides a framework for studying the design approaches of the Open Systems Analysis and the EPAS/IPSO (Entree Processus Accumulation Sortie/Input Process Store Output) Approach. The former is given as an example of a well known conceptual approach which is purely functional; the latter is presented as a generalization of the Open Systems Analysis which includes the principle of autonomy of systems. The EPAS/IPSO Approach's applications are then related to the design of any kind of system: material, informational, organizational, biological, or temporal. Finally, the Generalized EPAS/IPSO Approach is introduced as a way to develop even more complex systems by providing conceptual tools to design expert systems. (Author/JB)

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ISSN-0225-0667

ED261674

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THINKING AND THE DESIGN PROCESS

Bernard MOULIN

Rapport de recherche
DIUL-RR-8414

IR011826

Mai 1984

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THINKING AND THE DESIGN PROCESS

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ABSTRACT

Design methods are based on concepts and techniques which are ways of describing the results of a thinking process related to a specific subject. Concepts and techniques have a large influence on the thinking process because they provide the elements which compose the representation of ideas. We examine here three main phases of the design process: understanding the context of a problem, identifying the problem and finding a solution. These phases involve processes such as learning, reasoning, modelling and creating. These processes are presented thanks to the introduction of the notion of mental representation, which is built on the base of associated concepts. This model provides a framework to study current design approaches.

The Open Systems Analysis is given as an example of a well known conceptual approach which is purely functional. The EPAS/IPSO Approach is presented as a generalization of the Open Systems Analysis, more particularly with the introduction of the principle of autonomy of systems. Its applications are related to the design of any kind of systems: material, informational, organizational, biological, temporal systems. The Generalized EPAS/IPSO approach is introduced as a way to develop even more complex systems. It provides conceptual tools to design expert systems.

1. THE DESIGN PROCESS

1.1 Introduction

It may be surprising for the reader to find in this paper a discussion about the design process. Many people are designing systems, plans; Many techniques have been developed in various domains to design things... Consequently most people do not ask questions about the design process assuming that if we know design techniques, the design process is naturally and perfectly understood by all designers.

However the design process is at the center of numerous creative activities. Any design task is initiated by a need, a demand or a problem which applies to a specific part of the «Real World». Three major skills are involved in the design process (figure 1): Communication skills help understand the demand and explain the solution when it has been found; understanding skills help understand the design problem according to a given knowledge; creativity skills help find or generate a solution to the problem. Thinking may be considered as a basic intellectual activity which enables communication, understanding and creative processes, and hence the design process.

We will focus our attention on the design process in computer science activities such as information systems design, data bases design, expert systems design... However the results and conclusions we will reach may be applied to any other design activities.

The design process may be carried out either on an object of the «Real World» or on a model of that object: a painter may sketch a drawing directly, but an engineer will design blue points, and models, before a bridge will be really built. It should be noted that even design activities which seem to apply directly to the Real World, involve a phase during which a model is conceived: it is a mental model. Modelling is a basic activity of the design process. In this section we will introduce the modelling

process and the concept of mental representation of objects; we will distinguish the processes of learning and creating and finally we will study the design process.

1.2 Modelling and mental representations

We may model various kinds of things or activities: a model may be a reproduction of an object, it may also represent only some characteristics or functions of an object; it may be used to represent the reality, or to simulate a behaviour of a given object... We model various types of objects: cars, houses, bridges, engines, computers, solar systems, nuclear systems, biological systems, economical systems, organizations, companies, financial systems, educational systems, methods, reasoning processes, concepts... Anything may be modelled.

We may identify several phases composing the modelling process:

1. to understand the subject (identify the study limits and the modelling goals);

2. to analyze or to identify the behaviour of the studied object in its environment;

3. to select a method which will be used for the description of the model (the model is designed as an «image» of the object);

4. to simulate or study the behaviour of the model and to compare it with the behaviour of the studied object. Depending on the results of the comparison, the model is modified and we get a «better image» of the studied object.

Usually the studied object is not precisely defined and the model is designed on the basis of few details concerning object characteristics; and when the model has been achieved users have a better idea about the object they need or model, and it is usually different from the model at hand. Prototyping techniques are used by designers to help users identify systems characteristics that they really need.

A difficult question arises at this point. How do we think about a given object ? What is the representation of an object in our mind when we think about it ? Many researchers, scientists and philosophers have proposed answers in different fields of cognitive science: psychology, linguistics, philosophy, computer science (SOWA84).

We will introduce here the concept of mental representation of objects. When you think about an object which is precisely identified (a person X, and object Y, a location Z...), a «mental image» of this object appears in your mind, and the precision of this image depends on the way you are familiar with this object. If the object corresponds to an event you have experienced, the mental image of this object is composed of the various scenes which characterize this event in your mind. When you speak about an object which you don't know or which is abstract, your mind try to find a representation for it. In such a situation you may use different techniques to help characterize the new concept: analogy with a well-known object; invocation of instances of this object; characterization of the object behaviour with references to concepts you have in mind...

Mental representations may be very complex and in our mind a given object may have several representations (visual, auditory...). It is not our purpose here to study these representations: we only assume that they exist in our minds and that they are composed of associations of concepts; a concept should be defined as an atomic element of a mental representation. Concepts are related together by means of mental associations which correspond to our understanding of the Real World. In the diagrams of this paper we will represent symbolically concepts as little circles and associations (or relations) between concepts by lines attached to the circles.

A mental representation may be visualized as a network of concepts. To understand an object means that we are able to relate its mental representation with the other concepts or other mental representations we have in our mind.

To learn consists in establishing mental associations (or relations) and to know means that we are able to invoke or to follow mental associations between concepts in our minds.

When we create or conceive a new object, the mental process is somewhat different as the interrelated concepts which represent this object do not exist in our minds before the creation.

We may suggest that learning and creating are «dual processes»:

- to learn a concept X consists in establishing mental associations between the new concept X and the conceptual structure of well-known mental representations;

- to create a concept Y consists in inventing the missing concept which fits into preexisting mental associations of a conceptual structure of well-known representations.

Figure 2 illustrates the processes of learning and creating. Solid lines represent known concepts or associations, whereas broken lines represent new concepts or associations.

Finding a solution to a given problem, designing a new system or a new object are examples of the mental phenomenon of creating.

1.3 The Design Process

We will examine here three main phases of the design process: understanding the context; identifying the problem; finding a solution.

1. Understanding the context: we identify the relevant area of our preexisting conceptual structure, and we learn new concepts related to the study (we establish associations between the preexisting conceptual structure and the new concepts we are learning). The new conceptual structure corresponds to the context of the problem (see figure 3). Usual problems encountered by designers are related to the communication of knowledge (how to identify or establish the right associations between concepts ?).

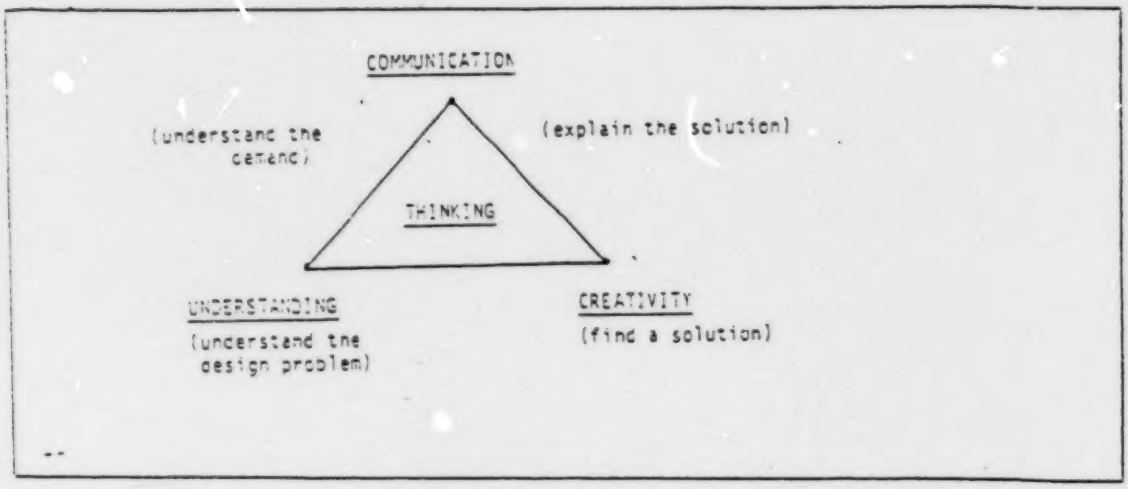

Figure 1: the basic triangle of the design process

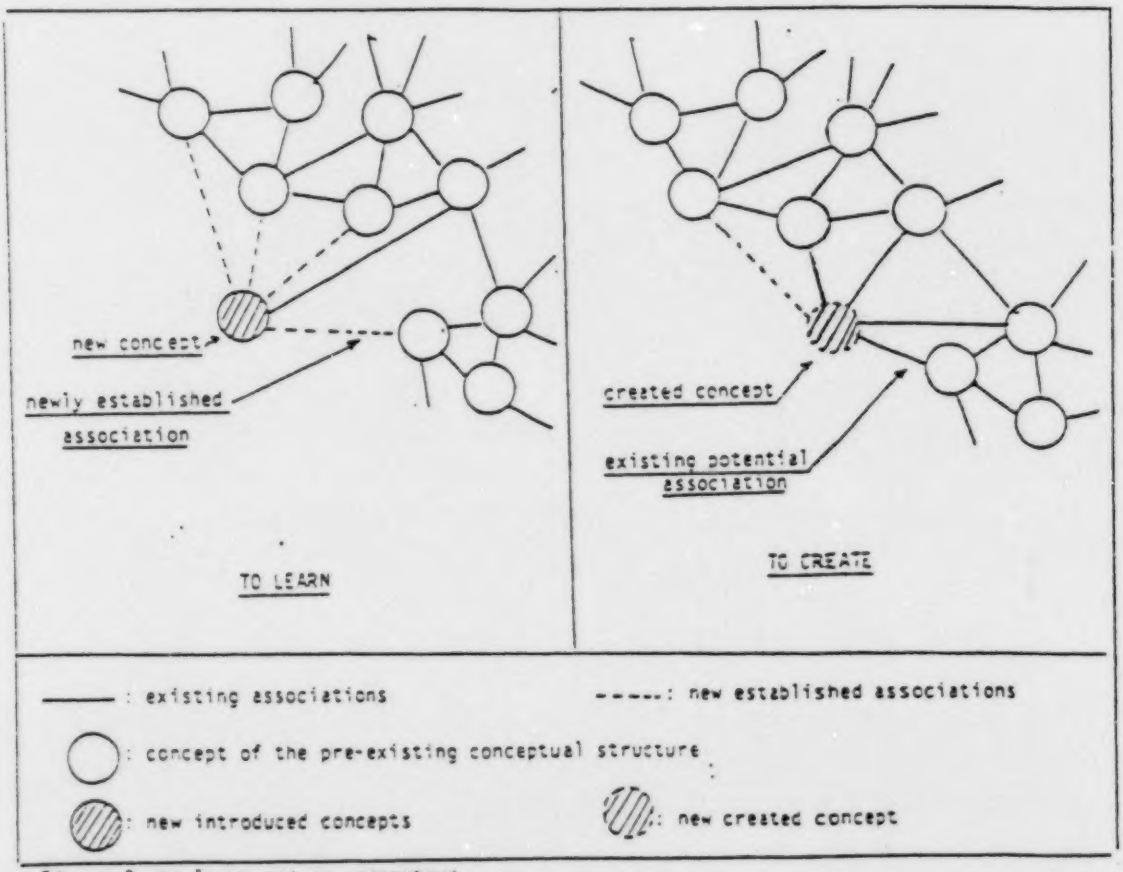

Figure 2: to learn and to understand

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2. Identifying the problem: the process consists in finding anomalies in the new conceptual structure (the context) according to «aesthetics rules». We try to find erroneous associations or missing concepts according to rules (often unexpressed) which characterize the conceptual structure in the context of the problem.

3. Finding a solution: consists in modifying the conceptual structure to avoid anomalies. We propose new associations or new concepts which fit better in the conceptual structure according to the rules related to the context of the problem.

The reader may now imagine his or her knowledge as an intricate network of concepts and may be curious to know how the mind is able to use that knowledge. We cannot explain the exact mechanisms of these mental manipulations, however we are able to explain some general principles. Psychologists have shown that the human mind can only manipulate a limited number of concepts at a time, and everybody can experience that. Given any context (visual, auditory, intellectual...) we first perceive global characteristics or general patterns, before we notice or understand details. Designers are obviously dealing with this mental phenomenon and have coined various expressions related to it: Top Down Approaches, or Abstraction Techniques... A problem or a model is first studied from a general point of view, before details are taken into account.

This remark can help us illustrate the way we find solutions or create new concepts (see figure 4). First we identify the area in the preexisting conceptual structure where there is an anomaly (figure 4 no 1). Then we try to find associations between missing objects and the conceptual structure within this area: (figure 4 no 2). Finally we create one or several concepts which fits with the «pending associations», and we improve the conceptual structure around the new concepts (figure 4 no 3). The reader will find numerous examples of this creative process. Let us only suggest the case of the translation of a sentence in a foreign language. The area corresponds to the part of the conceptual network which joins the concepts of the sentence expressed in the mother tongue. Some associations join these concepts with equivalent concepts in the foreign language. The

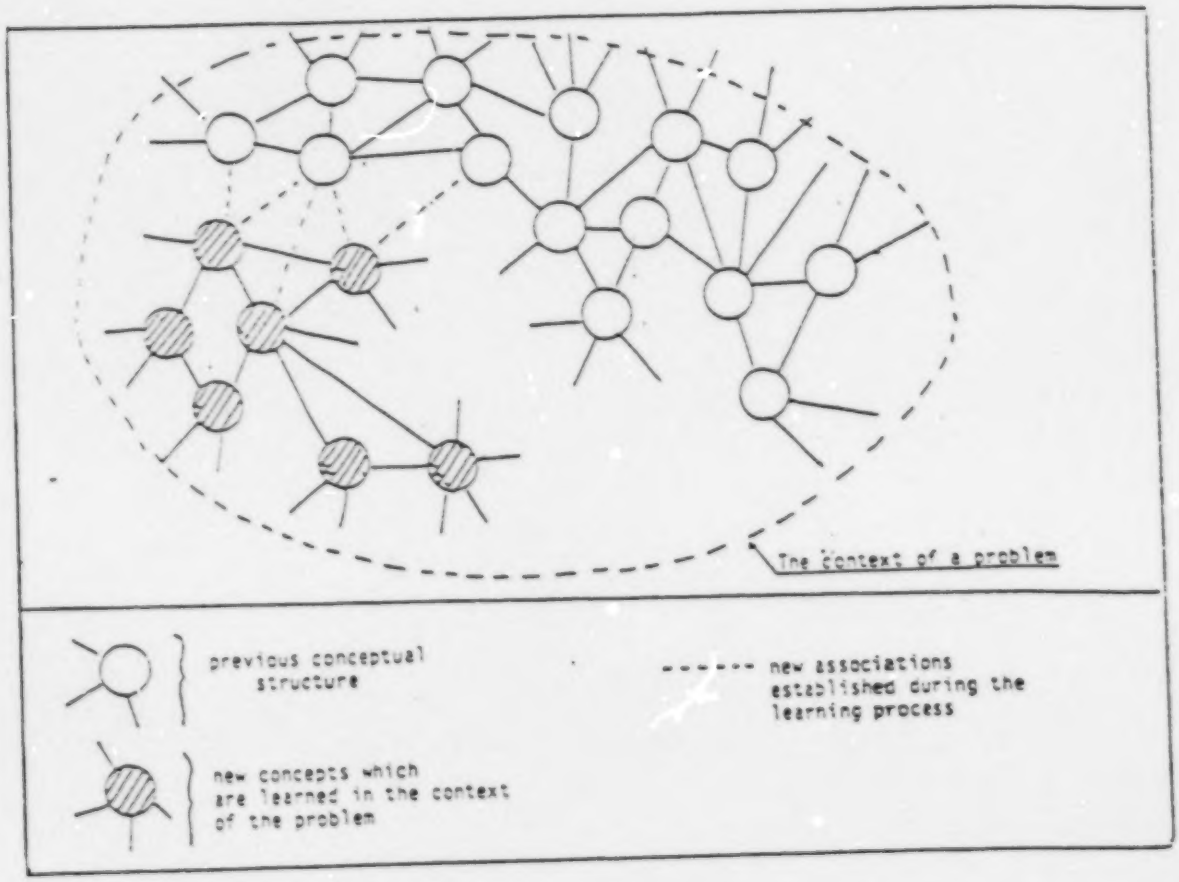
The context of a problem
previous conceptual structure
new concepts which are learned in the context of the problem
new associations established during the learning process

Figure 3: the context of a problem

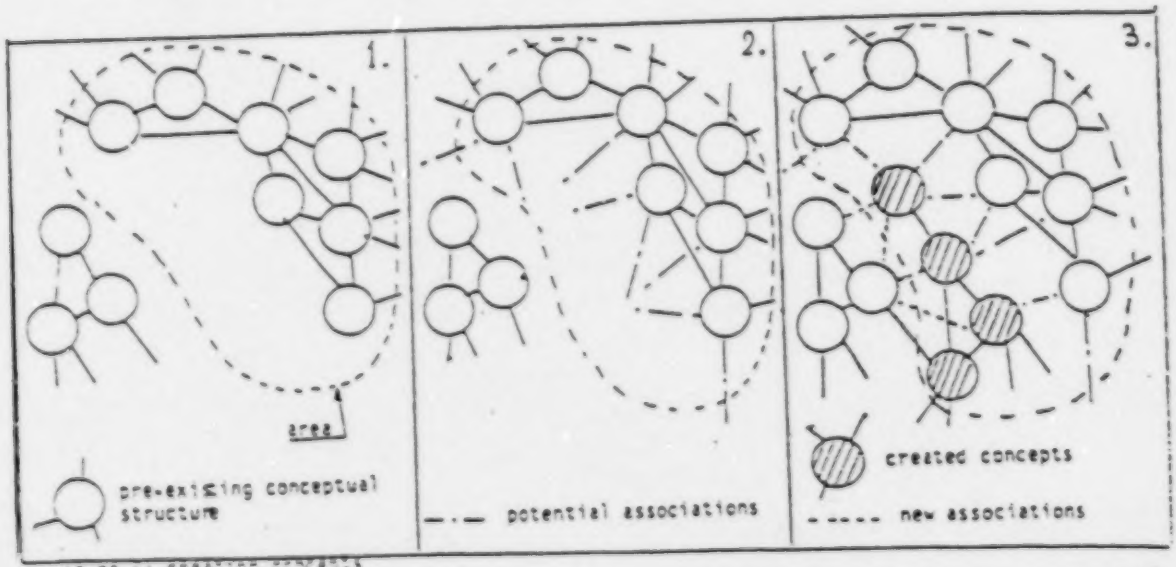

Figure 4: creating concepts

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problem arises when we do not know the translation of one word. All the associations are ready but the concept is missing. The solution is obtained either by looking for the missing word in a dictionary or by establishing in the area a new concept (called a paraphrase) created from other known concepts.

1.4 Synthesis

Our purpose in this section was to identify the basic characteristics of the design process and to introduce a model which helps simply illustrate the complex mechanisms of the design activity. This model will help us to present the current design approaches which are used in organizations, and to explain how they could be improved in order to manage more complex designs.

2. CONCEPTUAL STRUCTURES IN ORGANIZATIONS

Each person possesses his or her own conceptual structures in his or her mind; these conceptual structures have been built thanks to education and experience. When different persons interact (work on the same project, discussion, communication...) they must share the same subset of conceptual structures, which is needed for this interaction. Otherwise these persons would be unable to understand each other and the interaction would be impossible. When a system (organizational, computerized...) is developed in an organization a common subset of conceptual structures must be identified so that the system will fit into the organization, and people will understand its use and purpose. The main problem of the design process is related to the identification of a common subset of relevant conceptual structures.

In organizations each object may be referred to in several ways: its material shape (architecture, colors...), a textual representation, a graphical representation... Data analysis deals with textual representations of objects and data structures (TL82). Information systems analysis deals with a symbolic representation of systems structures and data flows

(CRIS182) (CRIS183). Software design develops specific implementations of systems using computers. Simulation studies some behavioural aspects on models which represent objects of the Real World. Expert systems (LEN83) deal mostly with mechanisms and rules which characterize the behaviour of systems... We should note that in each of these disciplines designers have introduced different formalisms to model systems according to their specific design goals (conceptual data structures, data flow diagrams, transition diagrams, information flow diagrams, semantic nets...), but all these representations use different symbols to develop conceptual structures (SOWA84).

Open Systems Analysis (VONB56) is an example of a «conceptual approach» which is very useful for designers: the almost universal use that is made of it in scientific disciplines proves the necessity of such approaches for analysis and design. The strength of Open Systems Analysis is no longer to be proved, yet one can note that the concept of «open system» («input», «process», «output» and «environment») does not permit the complete representation of every real phenomenon. This approach is purely functional: The designer is led to think about a reality in terms of functions that are associated with one another in a sequential and deterministic arrangement. Moreover it is difficult to express the notions of time and inherent dynamics when it comes to real phenomena. Let us take the example of figure 5 which illustrates the communication chain between person A and person B. This representation helps understand what the different transformations of information are along the chain, but it would be very complicated to model accurately the discussion which takes place between person A and person B and which is recorded on a tape recorder.

The «cybernetics paradigm» (Bertalanffy, Wiener, Ashby) provides the «principle of the black box», the characterization of the process by the functions it plays, and the notion of «feedback» and «systems regulations». In computer science people speak about the modular design of systems. The «paradigm of hierarchical systems» (Mesarovic, Wiener) provides the concept of «multi level systems», «global process versus local process», and decomposition techniques. In computer science, people deal with «structured techniques», «top down approaches»...

This functional approach has spread a «cybernetic view of The World», but it has limitations when the studied phenomena do not correspond to such a functional behaviour. Most of the systems cannot be modelled with a «functional approach, when we come up to a certain degree of complexity. This is true for most organizational living and even artificial systems, when notions of dynamics, synchronization, autonomous behaviour are concerned.

We proposed generalizing the open system analysis by introducing «the principle of autonomy of systems», which helps to model systems in a more general way (MOU83b).

3. THE EPAS/IPSO APPROACH

3.1 Concepts and Principle of Autonomy

According to the «principle of autonomy» (MOU83b), an autonomous system is a conceptual tool which enables us to characterize the specific behaviour of an object (material, temporal, organizational, living objects...). The behaviour corresponds to the rules of evolution (or the reaction) of this object in response to interaction with other objects or its environment. A system may be composed of several autonomous component parts, which cooperate in the system's evolution towards a specified goal or «finality». Each autonomous component part has a specific behaviour which corresponds to «its rules of reaction» in response to interactions with other component parts of the system, or with its environment. Consequently each autonomous part of a system may behave according to «its own time basis», and the cooperation of the various component parts of a system may be seen as a coordination phenomenon to help control the evolution of the system towards a specified goal. The evolution of the system may be viewed as the result of coordinated activities of its component parts: During its evolution the system reaches different states characterized by the accumulation of materials, data or information.

The following concepts are introduced to support the description of systems according to the principle of autonomy of systems. Each autonomous component part of a system will be represented by a PROCESS, characterized by functions that depict the behaviour of the system. A process is linked to its ENVIRONMENT by FLOWS OF MATERIAL or FLOWS OF INFORMATION. The system is characterized by accumulations of material or information in STORES which are joined to the processes by CHANNELS, most of which are bidirectional. These channels permit the exchange of information or material between processes and stores.

Consequently a system will be modelled in the form of a double network of processes and stores which are interlinked. The stores are associated specifically with a given process or they are linked to several processes. In the latter case they ensure the link between different autonomous parts of the system. Each process can have a behaviour that is completely autonomous, reacting to the changes that occur in the stores to which it is linked and reacting to the flows from the surrounding environment. Figure 6 gives an example of an IPSO diagram in which the system «recorded conversation between person A and person B» is designed at a global level. The following presentation guide provides a description of the system.

The system is composed of three autonomous processes. Process P1, «conversing A» represents person A; it is linked with mind A (E1) which gives directives to P1 during the conversation. P1 expresses ideas of A in the form of sentences from A (A4) and interprets sentences from B (A5). Process P2 «conversing B» represents person B; it is linked with mind B (E2) which gives directives to P2 during the conversation. P2 expresses ideas of B in the form of sentences from B (A5) and interprets sentences from A (A4). Process P3 «recording conversation» records information from sentences from A (E3). (A broken line around stores A4 and A5 is called a regrouping of stores and help simplify the representation with fewer channels).

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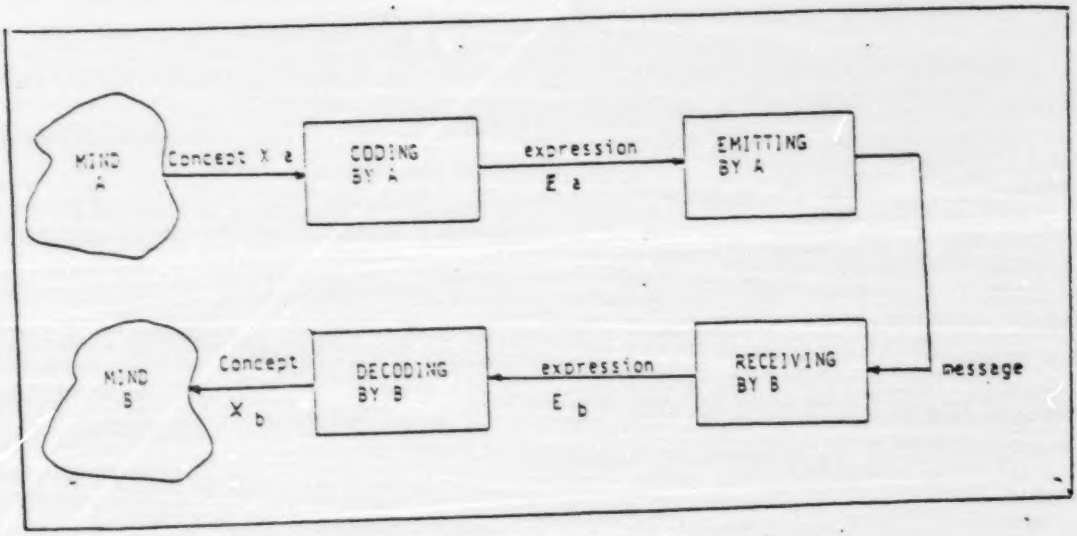

Figure 5: Communication chain when person A. speaks to person B.

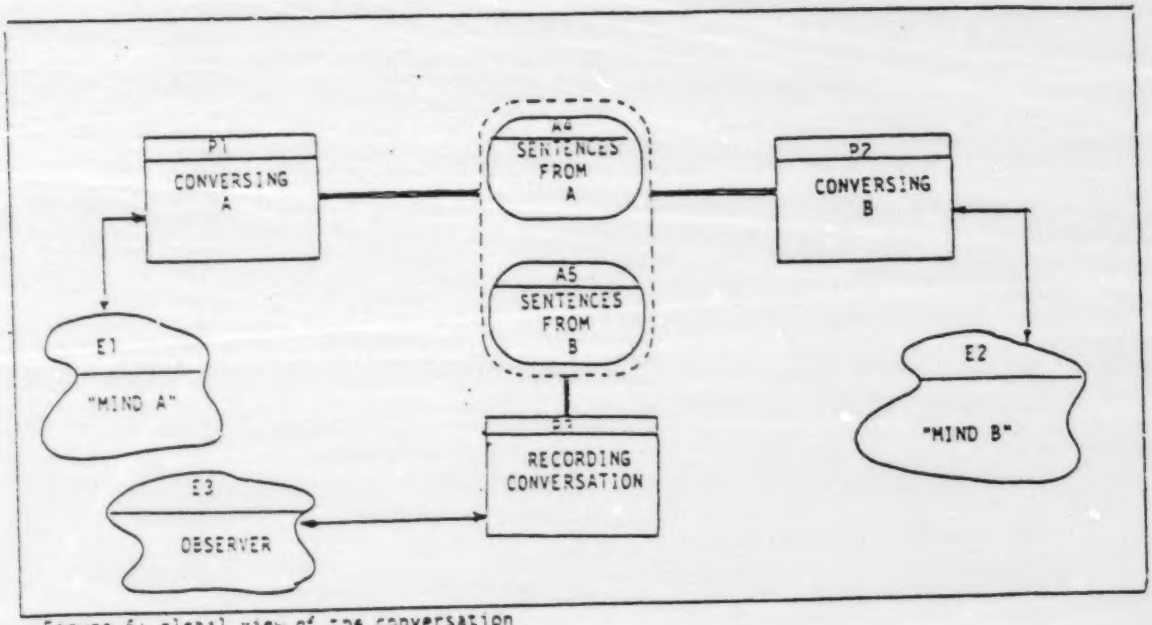

Figure 6: global view of the conversation

3.2 The conceptual approach E.P.A.S./I.P.S.O.

We will briefly summarize here the important points concerning the conceptual approach which implements the principle of autonomy of systems (Input - Process - Store - Output approach or Entrée - Processus - Accumulation - Sortie in French) (MOU83a) (MOU83c).

1. Before modelling we will specify the modelling perspectives that set the aims of modelling as well as the limits of the system that is analyzed (its environment). This is a very important phase, for it enables us to clarify the goals of the analysis which is particularly useful for complex problems.

2. We can try to answer to the following questions in order to study an autonomous system («it» stands for «the system»):

   - What does it do ? (identification of the function of the system)

   - What does it receive ? Where from ? (inputs from the environment)

   - What does it supply ? To whom? (outputs to the environment)

   - What stores does it use ? (identification of stores)

3. The «principle of focalization» is the application of the principle of «general to specific design» (or top down approach see points 1.3 and 2). Actually we use a method similar to that used when you make observations with a microscope. The study of an autonomous system can lead to the identification of various autonomous processes that are interrelated. With the E.P.A.S./I.P.S.O. approach the principle of focalization enables us to study each of these processes in the same way. It should be noted that a different modelling perspective is used each time. In figure 7 we represent an IPSO diagram which is the result of the application of the focalization principle on processes P1 and P2 of figure 6. We only give here a presentation

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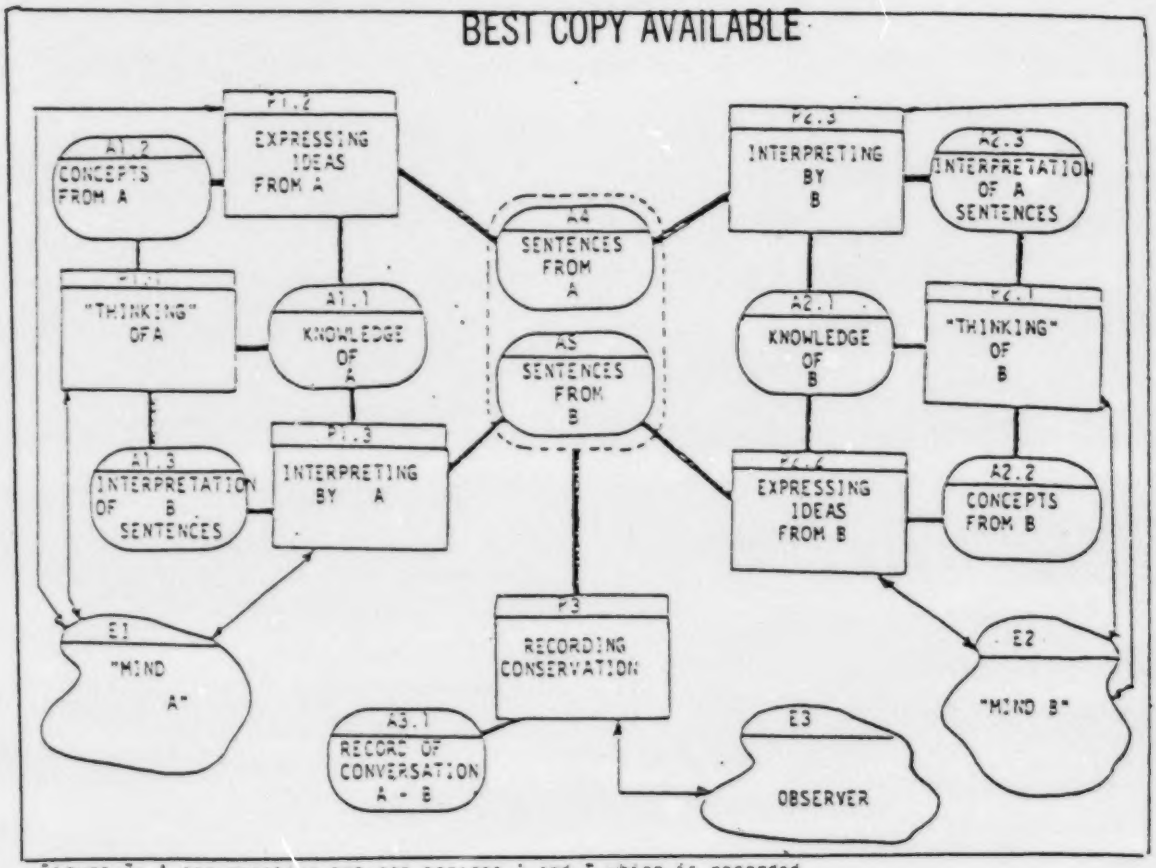

Figure 7: A conversation between persons A and B which is recorded

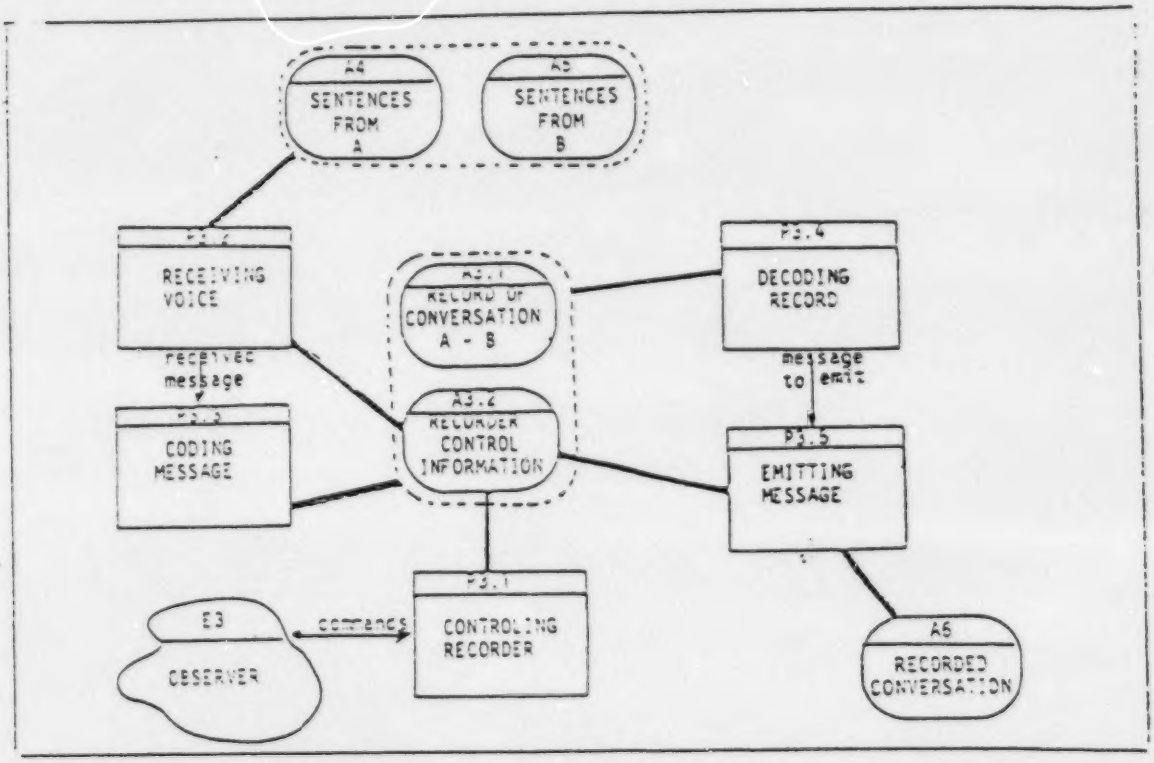

Figure 8: Focalization on the process P3: Recording conversation

guide for the details of P1. The process P1 «conversing A» is composed of three autonomous component parts, each of which is controlled by «mind A» (E1). The process (P1.1) «thinking of A» uses the knowledge of A (A1.1) extensively to understand interpretations of B sentences (A1.3) and to elaborate concepts from A (A1.2). The process (P1.2) «expressing ideas from A» transforms concepts from A (A1.2) into sentences from A (A4), and process (P1.3) «interpreting by A» transforms sentences from B (A5) into interpretation of B sentences (A1.3). Processes P1.2 and P1.3 use the knowledge of A (A1.1) extensively.

4. Each I.P.S.O. diagram (or diagramme E.P.A.S. in French), a representative schema of the modelled system, is verified by a simulation of the system's behaviour, and this on the basis of scenarios that are proposed by the designer. An I.P.S.O. diagram is documented by a presentation guide, which is an explanatory text, an example of which can be found in paragraph 3.1. Figure 8 gives a global view of the implementation of the EPAS/IPSO Approach.

3.3 Structural level - Functional level

A question may arise at this point. When should we use the principle of autonomy of systems, since systems are usually represented in the functional way of open systems analysis ? In fact we can distinguish two levels for the design process: the structural level and the functional level.

- The structural level implements the principle of autonomy. Consequently at this level we model systems which are composed of various autonomous parts and which are characterized by a higher degree of complexity. An I.P.S.O. diagram at the structural level is composed of Processes (P), Stores (S), Environment (E) which are linked by Flows (F) and Channels (C), where only the following associations are allowed:

(E-F-P); (P-F-E); (P-C-S); (S-C-P).

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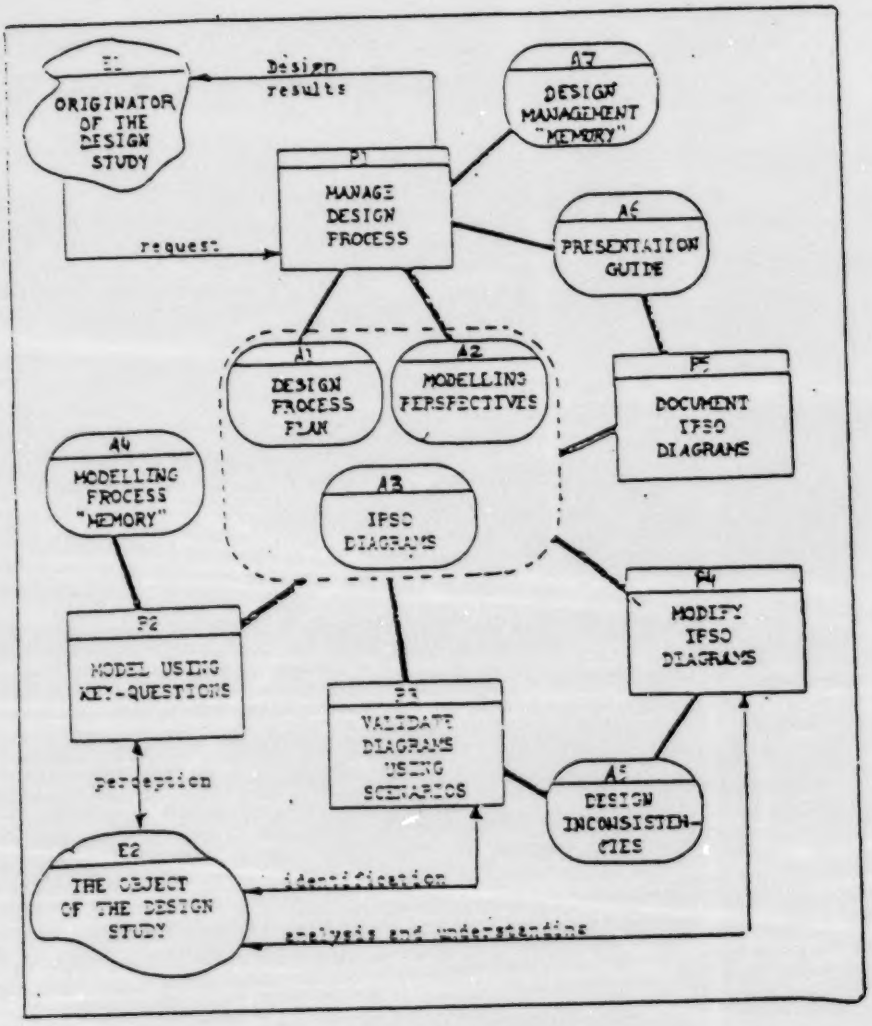

Figure 8: A global view of EPAS/IPSO Approach

These rules indicate that each process in the diagram is truly autonomous. Figures 6 and 7 gives examples of I.P.S.O. diagrams at the structural level.

When modelling at the structural level, the designer is able to describe the frame of the system (its structure) from a general point of view, and he does not have to care about how the system should work in specific conditions. The principle of autonomy provides indeed an effective tool to design complex systems, because at this level of abstraction it is most important that the concepts support the design of the essential components of the system, without disturbing the modelling process with superfluous details. Consequently it appears that the I.P.S.O. diagrams describe systems at the structural level with a great degree of generality, and that it is possible to derive different design results from them depending on the way the system is implemented. Thus a system is studied first of all at the structural level and the various I.P.S.O. diagrams obtained implement the principle of autonomy: these diagrams occupy different sublevels, where the upper diagrams provide a general view of the system and the lower diagrams provide a detailed view of the system. When the principle of autonomy cannot be applied anymore for the description of a subsystem, the functional level of the design process has been reached.

- The functional level implements the functional way of designing systems (section 2), similar to the Open Systems Analysis. The modelling process aims at describing, how the system works in specific conditions at this level. The I.P.S.O. diagram is composed of the same concepts as at the structural level, but now the following associations are allowed:

(E-F-P); (P-F-E); (P-F-P); (P-C-A); (A-C-P).

These rules indicate that the processes may be linked together by flows of data or information. As a result such processes are no longer autonomous and become dependent on information controlled by other processes. Figure 9 has been obtained when focalizing on process P3 of figure 7. This diagram belongs to the functional level.

Process P3 «recording conversation» is composed of 5 component parts. Process (P3.1) «controlling recorder» reacts to commands of the observer (E3) and manages the recorder control information (A3.2); All processes P1.2 to P1.5 take information into (A3.2) to synchronize their activities. Process (P3.2) «receiving voice» gathers information from sentences from A (A4) and from sentences from B (A5) and transforms them in received messages, which are treated by process (P3.3) «coding message». Process (P3.3) transforms received messages into the record of the conversation A-B (A3.1). Process (P3-4) transforms the content of record of conversation A-B (A3-1) into message to emit, which is treated by process (P3.5) «emitting message». Process transforms the message to emit and provides the recorded conversation (A6) which can then be listened to.

The functional level corresponds to a more traditional way of describing systems, which is implemented in such approaches as Data Flow Diagrams (YOU79) (G-S79) or Petri Nets (BRA83).

- The product of the modelling process depends on the type and the extent of the study. In general we will obtain a set of I.P.S.O. diagrams at the structural level, which provides a general view of the system, and a set of I.P.S.O. diagrams at the functional level which describes how specific parts of the given system are implemented.

3.4 Applications of this approach

The E.P.A.S./I.P.S.O. Approach can be used in a wide variety of applications which deal with the design or description of systems. We use it to design information systems in organizations (MOU83a), and we have elaborated an Information System Design Methodology (MOU83c). This methodology is taught to our students at the graduate and undergraduate levels, and they apply it to develop various design projects submitted by companies and public agencies use it too.

This approach can be used as a framework to describe, characterize and compare various information system design methodologies. It can also be useful to develop expert systems. In the next section we will introduce a generalization of E.P.A.S/I.P.S.O approach which provides a powerful tool for the design of complex systems.

4. GENERALIZED E.P.A.S./I.P.S.O.

4.1 Motivations and foundation

E.P.A.S./I.P.S.O. approach provides designers with a formalism and a method to model systems, in which processes and stores have conceptually the same importance. Consequently I.P.S.O. diagrams help combine in a single conceptual representation both behavioural and static characteristics of systems. It is an important property since designers are not led to neglect one or the other of these aspects as it is still the case with more traditional approaches (process oriented or data oriented methods (CRIS182)). Consequently the E.P.A.S./I.P.S.O. approach helps integrate data structures modelling methods, information flow descriptions and software development techniques (MOU83c).

We will try to explain here why this approach has such properties. First of all we must note that I.P.S.O. diagrams implement a way of designing conceptual structures which is very close to our mental representations of objects (paragraph 1.1): processes and stores represent the concepts; channels represent the associations of concepts; environment and flow are only used to represent the system limits. This explains why most people find that designing systems with such an approach is an easy exercise.

Secondly we will notice that E.P.A.S./I.P.S.O. approach allows designers to manipulate few concepts in each diagram, and to focalize on details in subsequent diagrams when they need to. This feature is also very close to our natural way of perceiving objects or problems (paragraph 1.3).

Thirdly we must note that the E.P.A.S./I.P.S.O. approach provides designers with means to easily manipulate abstractions according to their needs during the design process, without changing their usual design practice too much. This approach has been proven useful for designing all kinds of systems, especially in organizational environments.

Nevertheless the foundation of the E.P.A.S./I.P.S.O. approach is quite different from that of traditional systems analysis methods, and we will introduce here a new generalization which will reveal more accurately this difference. This generalization will be useful to design more complex systems, especially in the domains of expert systems and decision support systems.

Let us come back to the design process which can be defined as a problem solving process in which we must deal with incomplete information. In other words we must find a solution without knowing the exact terms of the problem, and all the means to solve it.

- Assumption: We will assume that there is always a conceptual structure (a network of processes and stores) which is a solution to a given design problem.

But usually this «ideal conceptual structure» is not known: it represents the goal of the design problem solving process. The designer will deal with incomplete information related to the problem domain, in order to propose a solution which should be close to the goal. The solution will be accepted if specialists estimate it is close enough to the «ideal solution». This feature explains the way people design systems: they use initial and approximate views of the problem, which are more and more detailed and adapted, as the design proceeds. (This procedure is often called refinement). This fact explains why designers work first at global abstract levels, and then try to find specific and detailed solutions. Everybody will agree that the global views are very important since they direct the design process towards the solutions, but it is also obvious that the global views are elaborated during a phase of the design process when the information at hand is very much incomplete. Each user or designer will only

perceive or design a part of the «ideal conceptual structure», which is composed of some more or less global elements, which are abstractions or aggregations of some parts of the «ideal structure». The I.P.S.O. diagrams may be interpreted as «abstract windows» opened on the «underlying ideal conceptual structure» according to the perception of the designer, and this remark may be applied to any type of modelling technique. Figure 10 illustrates symbolically this property of E.P.A.S. diagrams. Symbols (processes and stores) represented by solid lines represent «the ideal conceptual structure», which is the unknown goal of the design process. Symbols represented by broken lines no 1 represent how the system is perceived by one designer (processes P1, P2, P3, and store A4) at a given level of abstraction. Symbols represented by broken lines no 2 represent a different perception of another designer: he perceives processes P2 and P3; but instead of representing P1 and A3, he perceives stores A5 and A1.1 and process P1.1.

This modelling situation occurs from time to time, but usually designers avoid the problem, arguing that a design is somewhat a subjective task. However this characteristic of E.P.A.S. diagrams stresses a fundamental feature of the design process.

When we model a system we manipulate conceptual structures which represent our mental representation of the studied object. Since any object may be perceived quite differently depending on the goals of the modelling or even on the designer, the results of the design process may take various forms. However the design methods aim at providing a restricted set of concepts and design rules to establish a standard way of designing systems, which is highly desirable among the designers community. These remarks justify that design principles must be carefully examined. It is not our purpose to present such an analysis in this paper, but we will reconsider some design principles to introduce a generalization of the E.P.A.S./I.P.S.O. approach.

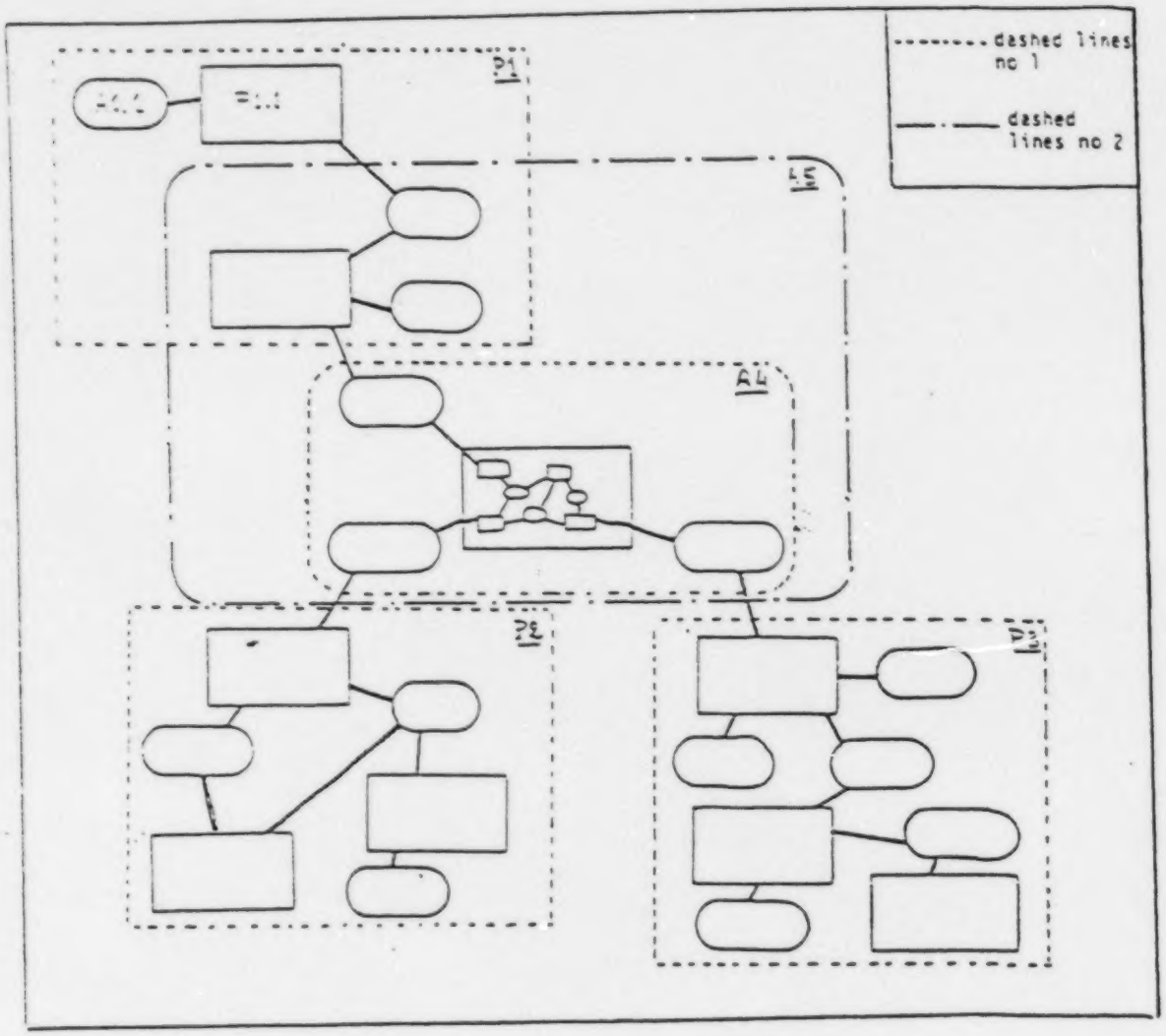

Figure 10: symbolic representation of various levels of conceptual abstractions

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4.2 Generalized E.P.A.S./I.P.S.O. approach

The first question we may ask concerns the concepts we use. Is it relevant to distinguish processes, stores and environments when some other approaches favor modelling using only one concept (for example the concept of object in object languages such as Smalltalk (SMAL82)). The use of two concepts such as «processes» to represent behavioural characteristics and «stores» to represent static characteristics of systems has been proven useful. And this fact is explained by the similarities of conceptual structures with our mental representations. The environment concept is introduced only to distinguish easily the system limits, but if the limits are changed we may discover that the environment is also composed of processes and stores. In the generalized E.P.A.S./I.P.S.O. approach we only consider 2 basic concepts: processes (P) and stores (S), linked by channels (C).

- At a given design level, the I.P.S.O. diagram is composed of a network of processes and stores based on the principle of autonomy of systems (paragraph 3.1).

- The design rules state that a unique type of association is allowed: (P-C-S) or (S-C-P).

- The focalization principle enables the expansion of either a process or a store, provided that the design rules be respected. This means that if a process is expanded its previous associations with stores must be preserved and implemented by means of associations of some of its sub-stores with the same processes.

Figure 11 gives an example of the result of a focalization on the store A4 in figure 6, when we consider that person A and person B are not speaking the same language.

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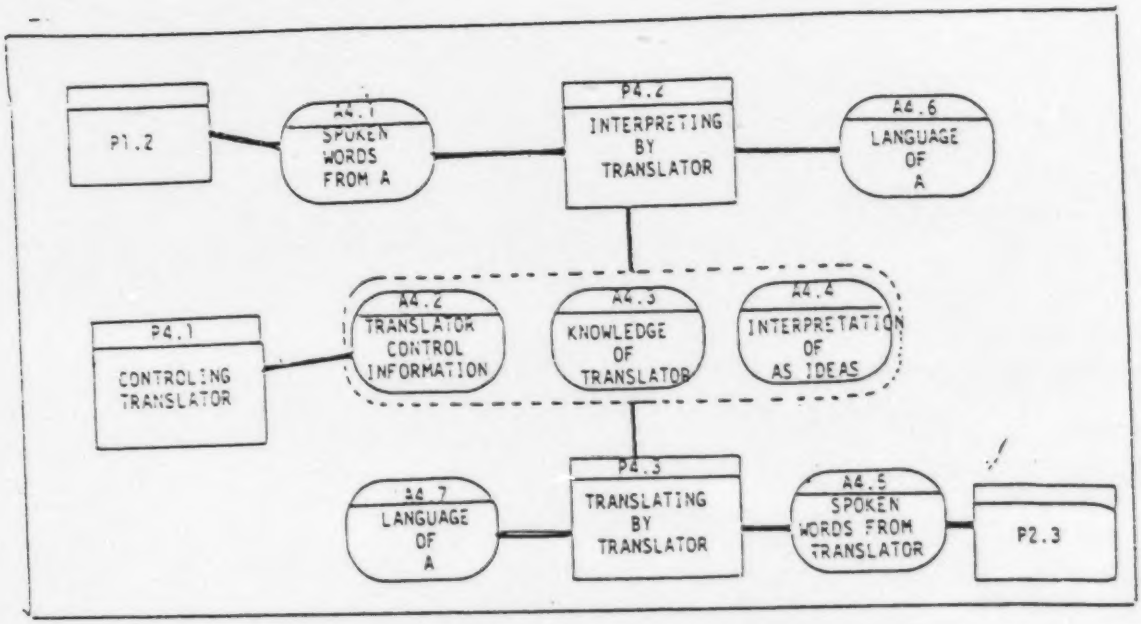

Figure 11: Focalization on the accumulation A4.

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Another question should be answered: when should we use the generalized E.P.A.S./I.P.S.O. approach ?

The Generalized E.P.A.S./I.P.S.O. approach takes place at the structural level, and should be used to modify and I.P.S.O. diagram when it does not provide a sufficient representation of the studied object, and that the solution consists in expanding a store.

More often the Generalized E.P.A.S./I.P.S.O. approach will be used to develop more complex systems such as expert systems, in which some component parts may behave in turn as processes or stores of informations (a characteristic we find in artificial languages: LISP...).

5. SYNTHESIS

Design methods are based on concept and techniques which are ways of describing the results of a thinking process related to a specific subject. Concepts and techniques have a large influence on the thinking process because they provide the elements which compose the representation of ideas.

We have examined three main phases of the design process: understanding the context of a problem, identifying the problem and finding a solution. These phases involve processes such as learning, reasoning, modelling and creating. These processes have been presented thanks to the notion of mental representation, which is built on the base of associated concepts. This model is used as a framework to present current design approaches.

The Open Systems Analysis has been given as an example of a well known conceptual approach which is purely functional. The E.P.A.S./I.P.S.O. Approach has been presented as a generalization of the Open Systems Analysis, more particularly with the introduction of the principle of autonomy of systems. The Generalized E.P.A.S./I.P.S.O. Approach has been introduced finally as a way to develop complex systems such as expert systems.

ACKNOWLEDGEMENTS

This Research is supported by the Natural Sciences and Engineering Research Council of Canada under grant nb A5518.

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